

CAAP Quarterly Report

Date of Report: *March 31, 2015*

Contract Number: DTPH5614HCAP06

Prepared for: Department of Transportation

Project Title:

Robust Anomaly Matching for ICIPs: Reducing Pipeline Assessment Uncertainty Through 4-Dimensional Anomaly Detection and Characterization

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For quarterly period ending: March 31, 2015

Business and Activity Section

(a)Generated Commitments -

(a)1.*Agreement Changes*

(a)1.1.*No changes to agreement*

(a)2.*Purchases*

(a)2.1. *Lighting for pseudo-pipe test rig - \$32.*

(b)Status Update of Past Quarter Activities -

(b)1.**Data Collection:** Reduced the speed of the data collection apparatus.

We have been able to collect data using the CSM Experimental Lab Test Setup using a surrogate pipe. Data were collected under variable conditions with two different types of sensors. All tests were run with different scan velocities. Data quality was sufficient for testing our feature detection algorithm.

(b)2.**Algorithm Implementation:** The feature detection algorithm was adapted to match locations both with and without odometry data. The algorithm with odometry is robust to tool velocity surges such as those that sometimes occur during real pipeline inspections. However, exact odometry is not required. Even “poor” odometry gets the algorithm close enough to the correct location to be sufficient. We have also implemented a similar approach that does not rely on odometry.

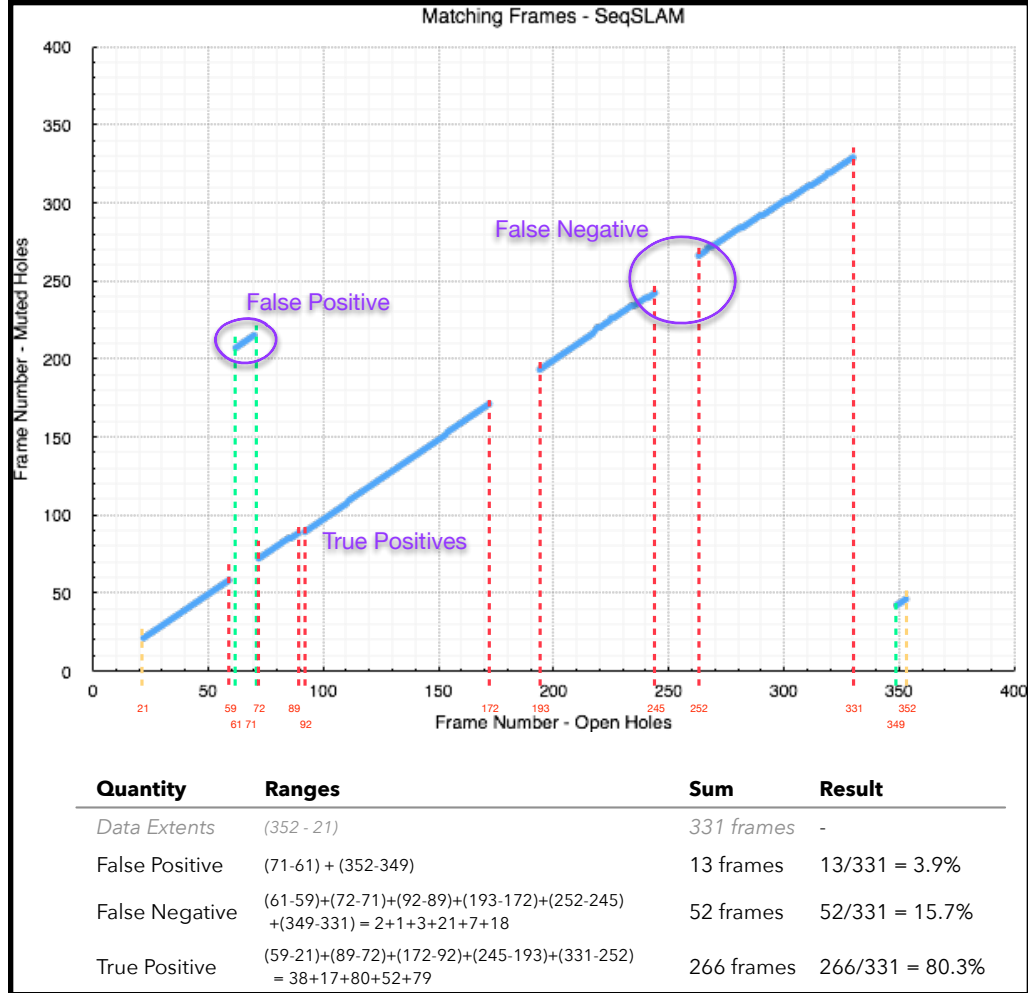


Figure 1: Results from matching two runs of laser scanner in pseudo-pipe.

(b)3.**Algorithm Preliminary Results:** We have constructed an artificial pipeline “run” consisting of five pipeline “segments”. Three segments in the “run” were featureless. Two segments contained synthetic “defects” - various sized holes drilled through the cardboard “pipe”. Scans were taken with a laser. In one set of experiments, the holes were open and deep. In the second set of experiments, the holes were covered and were a close match to the background intensity. See Figure 1. Our sensor, a scanning laser, traveled down the pipe, collecting data over 240 degree arc. Multiple data sets were collected from these two different configurations, with variations in the travel velocity of the sensor (to simulate real-world conditions). These set were then laced together to give sections of pipe that were 5 segments long. The algorithm was run on these 5-segment “runs”. The goal was to see if the algorithm could match up the features from the two different appearances.

(b)3.(a)With minimal optimization of the algorithm, we were able to achieve the following location matching rates:

- True positive: 80.3% - locations correctly identified as equivalent in two different data sets
- False negative: 15.7% - locations incorrectly identified as not matching

- False positive: 3.9% - locations incorrectly matched

(b)3.2. These preliminary results are encouraging. While the artificial holes are distinct, they are sparse. Additionally, there were long sections of featureless pipe that were virtually indistinguishable. We were able to achieve good matching (alignment) over these regions.

(b)3.3. The images below show a section from the open-hole dataset on the left and the equivalent matching frame from the covered-hole dataset on the right. These images demonstrate some of the limitations of our experimental apparatus.

(b)4. Identify Additional SAM candidate algorithms: In addition to the algorithm we implemented above, we have identified several other algorithms we would like to try. While these algorithms all use fundamentally different approaches to determine features, they all rely on visual descriptor matching. This leads to the potential need to examine visual descriptors.

(b)5. 2015 PRCI Research Exchange: Participated in the 2015 PRCI Research Exchange Meeting in Houston in February.

(b)6. Progress on stated objectives from last report:

(b)6.1. Test preliminary algorithm on synthetic data

complete

(b)6.2. Identify additional SAM candidate algorithms

complete

(b)6.3. Implement additional SAM algorithmic approaches

complete

(b)6.4. Modify test rig:

(b)6.4.1. Increase linear scan density

complete

(b)6.4.2. Lengthen test rig to accommodate 3 contiguous sections of "pipe"

complete

(b)6.5. Test SAM algorithm

(b)6.5.(a) Test against sparse visual data

complete

(b)6.5.2. Adapt for virtual frames and test

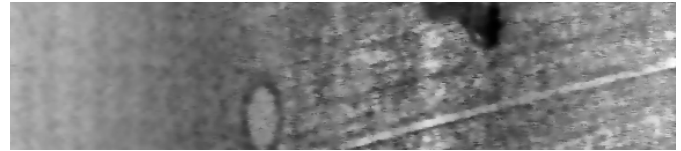
complete

(b)6.5.3. Test against multiple "pipe" segments with sparse anomalies

complete

(b)6.6. Implement Kalman filter with virtual frames and odometry

postponed indefinitely - not clear that this approach will be as



productive as the the approach taken.

(c) Description of any Problems/Challenges –

(c)1. The images below show a section from the open-hole LIDAR dataset on the left and the equivalent matching frame from the covered-hole dataset on the right. These images demonstrate some of the features and limitations of our synthetic data.

(c)1.1. Description:

(c)1.1.1. The seam in the cardboard tube (diagonal line in bottom right quadrant) is a good analog for a spiral weld.

(c)1.1.2. The holes are clearly represented at different depth resolutions. The bright holes on the left indicate deep holes. The darker holes on the right correspond to shallow and even reverse holes (filled with paper).

(c)1.1.3. The hole on the bottom left in the left figure is compressed in comparison to the corresponding hole in the right figure, indicating a faster scan velocity on the right.

(c)1.(b) Limitations:

(c)1.(b)1. Holes are geometric and distinct. This is a poor analog for the organic irregular shapes found in real corrosion.

(c)1.(b)2. Cardboard texture is visible in the scans. We are concerned that these patterns may be distinct enough that the algorithm may be matching on this texture.

(c)1.(b)3. We have no way of distinguishing between internal and external features.

(c)1.(b)4. Real scans may have a completely different dynamic range than the data we are using. We do not have a way to quantify how well our synthetic data models real data.

(c)1.3. Remedy:

(c)1.3.1. It will be very helpful to have some scan data from real ILI inspections. This data does not need to be identifiable. We could assemble a fake inspection run from various representative features from one or more real inspections.

(c)1.3.2. Since one of the objectives of this work is to be “sensor agnostic”, it will be useful to have representative data over the same set of anomalies using different sensors - MFL, EMAT, EMIT, and possibly other sensor types.

(c)2. We are still working to obtain any ILI data. We would like to have representatives of high and low resolution tools as well as representatives of different sensor types. Ideally this data will be over the same sections of pipe. If this is not possible, we could still learn a lot from data taken over different sections.

(c)3. When we get some sequential ILI scans, our next phase of research will be to develop a benchmark standard for current industry techniques for directly measuring corrosion growth using repeated ILI scans. This benchmark will serve as a point of comparison for the “improved” algorithms we are developing.

(d)Planned Activities for the Next Quarter –

(d)1. Stated objectives for Quarter 2, 2015

(d)1.1. Compare LIDAR dataset against a visual dataset as an analog for using different types of sensors.

(d)1.2. Research state-of-the-industry for directly measuring CGR with repeated ILI. Begin an experimental/survey paper for publication in ASME on this topic.

(d)1.3. Get some real ILI data. We are approaching multiple different operators. Barring this, we will do a literature search to develop a catalog of representative anomalies from publicly available sources.

(d)1.4. Examine the effectiveness of our current algorithm over repeated inspections. Use this as a baseline for future improvements.

- this requires real data

(d)1.5. Examine the impact of various data descriptors on the effectiveness of the matching algorithm. Compare against aforementioned baseline.

- requires real data

(d)1.6. The Graduate Student will begin an internship with Chevron’s advanced technologies group during the second half of this quarter. We expect this internship will enable and enhance the research significantly.